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"A micro-combustor system for the production of electrical energy"

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The present invention relates to a micro-combustor system for the production of electrical energy.

The present invention is based on the physical principle whereby thermal energy produced by a combustion is transformed into electromagnetic energy, which in turn is converted into electrical energy, for instance by means of photovoltaic cells made of semiconductor material.

The object of the present invention is to provide a micro-combustor system for the production of electrical energy with high efficiency of conversion of the thermal energy into electrical energy.

According to the present invention, this object is achieved by a system having the characteristics set out in the main claim.

The present invention shall now be described in detail with reference to the accompanying drawings, provided purely by way of non limiting example, in which:

- Figure 1 is a schematic perspective view of a micro-combustor system according to the present invention, and

- Figure 2 is a perspective sectioned view of a conversion device indicated by the arrow II in Figure 1.

With reference to Figure 1, the number 10 schematically designates a micro-combustor system for the production of electrical energy. The system 10 comprises a plurality of conversion devices 11, electrically connected to each other in series or in parallel, each of which is constructed as described hereafter. The system 10 comprises a pipeline of

conduits 12 to supply fuel and combustion supporter to the individual conversion devices 11, a pipeline 13 of exhaust conduits for the removal of gaseous combustion products from the conversion devices 11 and a network of electrical connections, for regulating generated power, for the electrical ignition of the combustors and for transporting the current from the combustor to the load resistance.

With reference to Figure 2, each conversion device 11 comprises a combustion chamber 14 made of material that is able to withstand high temperature. Preferably, the combustion chamber has spherical shape and is constituted by such material as to withstand temperatures in the order of 1500 - 2000 K.

The combustion chamber is preferably provided with means for the selective emission of electromagnetic radiation, preferably made in the shape of a lining 26 applied onto the outer surface of the combustion chamber 14. The combustion chamber is preferably constituted by a material with high heat conductivity (for instance tungsten or molybdenum), to allow the heat generated by combustion to reach the outer surface 26. At least a part of the inner surface of the combustion chamber 14 is preferably coated with a material with low heat conductivity of the meso-porous or nano-porous type with porosity coated by catalysing agents, having the function of lowering the combustion activation temperature and reducing emissions of polluting reaction products (for instance nitrogen oxides). The material with low heat conductivity can be interleaved with the material with high heat conductivity in the form of a composite.

The lining 26 preferably has a selective emissivity in a wavelength band of a few hundredths of nanometres. The lining 26 can for instance be

constituted by a micro-structure obtained directly on the outer surface of the combustion chamber, or a thin layer of oxide having a highly selective spectral emission (oxide of yttrium, thorium, cerium, europium, erbium, terbium, ytterbium or other rare earth).

The combustion chamber 14 communicates with a fuel injection conduit 15, with a conduit 17 for supplying the combustion support and with a conduit 18 for the exhaust of gaseous reaction products. The conduit 15 preferably has cylindrical shape with a conical terminal segment, in proximity to the micro-injection system 16, with a section that increases outwardly; the purpose of the conical terminal section is to assure that the combustion support substance is aspirated by Venturi effect. The conduits 15, 18 are preferably constituted by ceramic material, or other material with low heat conductivity, to prevent the heat of the combustion chamber to propagate by thermal conduction to the exterior. The outermost part of the exhaust conduit 18 is preferably metallic to allow exhaust gases to release their residual heat before leaving the conversion chamber. The conduit 15 may have an articulated shape, for instance a spiral or a coil, to prevent the combustion products from returning towards the micro-injector. Similarly, the exhaust conduit 18 can have articulated shape to favour the cooling of the combustion products. The supply conduit 17 is preferably connected to the injection conduit 15; alternatively, it can be connected directly to the combustion chamber. The conduit 17 for supplying the combustion supporting substance can be eliminated if a mixture of fuel pre-mixed with liquid or gaseous combustion supporting substance is injected into the injection conduit 15.

The combustion chamber 14 is closed and it does not exchange gaseous products with the exterior except through the conduits 15, 17 and 18.

Each conversion device 11 is provided with a micro-injection device 16 preferably constituted by an ink-jet injector, of the "bubble" type or of the piezoelectric type, able to inject drops of fuel or a combustion-support substance mixture of a volume of a few picolitres and with a frequency which can be controlled by means of a controller (30) from a few kHz to hundreds of kHz. Alternatively, if a gaseous fuel is used, the injection system can be constituted by a miniaturised Bunsen burner. The fuel injected by the injection system 16 penetrates inside the combustion chamber 14 through the injection conduit 15. Preferably, the gaseous fuel injected by the injection device 16 is selected within the group comprising: methane, propane, butane, hydrogen, natural gas or other fuels including the possibility of adding metallic particles to the fuel.

Each conversion device 11 comprises a hollow structure 19 forming a sealed conversion chamber 20, within which is obtained a vacuum or is contained an inert gas at low pressure. The combustion chamber 14 is located inside the conversion chamber 20 and the conduits 15, 18 extend through the walls of the hollow structure 19. The walls of the hollow structure 19 defining the conversion chamber 20 can be made of metal, if a vacuum is obtained in the hollow structure 19, or of ceramic material coated with a high reflectance layer, in all other cases.

The hollow structure 19 comprises an elliptical wall 21 and a planar wall 22, so the conversion chamber 20 has the shape of a rotational semi-ellipsoid with half-axes A and B. The dimensions of the axes of the

conversion chamber 20 may vary from a minimum of 3 to 50 times the diameter of the combustion chamber 14. The combustion chamber 14 is preferably positioned in the first focus of the elliptical surface. The inner surface of the elliptical wall 21 is preferably provided with a lining 23 having high reflectance over the entire emission spectrum of the source of radiation.

The planar wall 22 of the hollow structure 19 bears means for converting electromagnetic energy into electrical energy, schematically designated by the reference number 24. Said conversion means are preferably constituted by photovoltaic cells made of semiconductor material, preferably with a band gap in the order of 0.5 - 0.8 eV in order to maximise the conversion efficiency by Planck radiation with colour temperature of 1500 - 2000 K. In a preferred embodiment, the photovoltaic cell is of the Schottky type and the active junction is constituted by silica and aluminium. In the case of the selective electromagnetic energy the material of the cells 24 constituting the conversion means is selected in such a way that the band gap energy is slightly greater than the energy of the photons corresponding to the wavelength of maximum emission, in order to maximise the conversion efficiency at that wavelength.

The exterior face of the conversion means 24 is preferably coated by a reflective metal layer. The inner wall of the conversion means 24 can be coated by a layer operating on the electromagnetic radiation as a band pass filter. Said layer can be a multi-layered dielectric coating, a metallic coating at the percolation state, an anti-reflection micro-structure (for instance a grid with sub-wavelength period) or a photonic crystal.

The conversion means 24 are positioned in correspondence with the plane that is perpendicular to the greater axis of the ellipsoid and passing through the centre of the ellipsoid, in such a way that the radiation emitted by the combustion chamber 4 reaches the photovoltaic means uniformly. Moreover, also by means of the selected geometry, the radiation not absorbed by the conversion means 24 is reflected by the reflecting rear face or by the front surface of the photovoltaic cell 24 and falls back onto the combustion chamber 14 where it is absorbed.

The particular geometry of the conversion chamber 20 causes both the radiation emitted by the combustion chamber and reflected by the photovoltaic chamber 24, and the radiation emitted by the combustion chamber 14 and reflected by the inner walls of the semi-ellipsoid to be concentrated on the combustion chamber 14. This assures a maximum recycling of the electromagnetic energy within the conversion chamber and hence a minimisation of fuel consumption and a maximisation of overall conversion efficiency. The radiation reflected by the inner surface of the semi-ellipsoid or by the photovoltaic cell 24 is re-absorbed by the lining 26 with the same efficiency with which it is emitted thereby.

The heat developed by the fuel-support substance reaction warms the surfaces of the combustion chamber and is wholly converted into electromagnetic radiation. The dimension of the conduits 15, 18 extending within the conversion chamber 20 is such as to minimise the transfer of thermal energy by conduction between the combustion chamber 14 and the hollow structure 19. The radiation emitted inside the conversion chamber 20 impacts on the conversion means 24 which convert electromagnetic radiation into electric energy. The

electrical power generated by each conversion device 11 can vary from a few watts to some tens of watts. Each device 11 is provided with electrical contacts (not shown herein) which collect electrical energy produced by the semiconductor cells 24.

Maintaining a vacuum or sub-atmospheric pressure conditions inside the combustion chamber 20 allows to reduce the quantity of thermal energy dispersed by convection. Consequently, nearly all the heat developed by the combustion reaction is converted into electromagnetic radiation which in turn is converted into electrical energy by the conversion means 24. To obtain a vacuum or low pressure conditions within the conversion chamber 20, various known techniques for assembling components in a vacuum may be used.